GEOLOGY IN THE VICINITY OF THE 1982 MIRAMICHI EARTHQUAKE NORTHUMBERLAND COUNTY, NEW BRUNSWICK

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Plate 82-193 Geology in the vicinity of the Miramichi Earthquake ..... in pocket

GEOLOGY IN THE VICINITY OF THE 1982 MIRAMICHI EARTHQUAKE

INTRODUCTION

A magnitude 5.7 earthquake occurred in north-central New Brunswick at 8:53 a.m. AST on January 9, 1982. This was followed by major aftershocks at 12:36 p.m. (magnitude 5.1) on the same day and at 5:41 p.m. (magnitude 5.4) on January 11 (Berry *et al.* 1982). Other sizeable aftershocks occurred on January 13, March 31, April 2, and April 19.

The epicentral region is located in west-central Northumberland County approximately 75 km west of Newcastle and 63 km east-northeast of Plaster Rock. The area is accessible from the Plaster Rock-Renous Highway along two well maintained gravel roads - one running northwest from McGraw Brook and the other running north from Dungarvon River. Logging roads running along Indian Brook to Lyles Mountain provide immediate access to the disturbed area (Plate 82-193). Portable seismographs within 5 km of the epicentre outlined a zone of aftershock activity within a 6 km X 4 km area centred at 46°59'N and 66°37'W with a vertical extent of less than 10 km (Hasegawa 1982).

Previous geological mapping in the area includes one 1:126,720 scale Geological Survey of Canada map (Shaw 1936) and three 1:50,000 scale Geological Survey of Canada maps: Big Bald Mountain (Anderson 1970*a*), McKendrick Lake (Anderson 1970*b*), and Tuadook Lake (R. Skinner 1975). The area has also been mapped on 1:15,840 scale by the New Brunswick Mineral Resources Division

(Fyffe 1972*a*, *b*, 1979; Crouse 1979). The purpose of the present mapping carried out in early June of 1982 was to make a detailed structural study of the area in order to provide some constraints on the possible origin of the earthquake activity.

Overburden in the area is composed of bouldery ablation till ranging from 0.5 to 1.5 m in thickness. This morainal deposit marks the eastern margin of a major Wisconsin ice sheet that existed in the Tuadook Lake area prior to 11,200 B.P. Postglacial emergence had begun by 10,000 B.P. (Rampton and Paradis 1981). Extensive overburden and forest cover (Figure 1) restricts well-exposed outcrop to river sections and bull-dozed logging roads. Only these outcrops were examined during the present survey. Glacial striae in the area trend east-west.

The earthquake area lies along the axis of the northwest-trending Miramichi Geanticline (Wade *et al.* 1977) or Anticlinorium (Rodgers 1970) or Massif (Fyffe *et al.* 1981). The Massif is underlain by Ordovician and older sedimentary and volcanic rocks, foliated Ordovician granite and gabbro, and massive Devonian plutonic rocks predominantly of granitic composition. The abundance of granitic rocks suggests the Massif is underlain by thick continental crust.

COUNTRY ROCKS

The greatest part of the map-area is underlain by rocks of the Devonian North Pole pluton (Crouse 1979; Fyffe *et al.* 1981). The country rocks surrounding the pluton are composed of sedimentary and probable volcanic rocks of the Ordovician and older Teta-

Figure 1. Forest cover looking north toward Hickey Lakes.

gouche Group and are intruded by foliated Ordovician granite.

Quartzite and phyllite (Unit Os): This unit comprises interbedded grey quartzite and phyllite found south of the Little Southwest Miramichi River along the southern margin of the Devonian pluton and as a large roof pendant within it to the northwest. Bedding, up to 0.5 m thick in quartzite, is folded around axes plunging moderately southeastward (Figure 2). Change of bedding trend to the northeast from the general southeast direction is due to later folding.

Within 2 km of the granite contact, there is a noticeable increase in abundance and size of mica flakes on cleavage surfaces and phyllitic rocks are spotted with dark grey porphyroblasts of cordierite and andalusite (Figure 3). An outcrop on the road south of the bridge over the Little Southwest Miramichi River within 200 m of the unexposed contact, is a migmatite containing rafts of porphyroblastic pelite set in a psammitic matrix.

Quartz-feldspar porphyry and amphibolite (Unit Op): A sequence of interlayered grey foliated quartz-feldspar porphyry and dark green amphibolite is found along the eastern contact of the Devonian granite. The less plentiful amphibolite occurs in layers about 1 m in thickness. Layering generally strikes northeastward and dips gently to the west, but near the contact, the trend is to the north and dips are steep. A massive 30 cm granite dyke concordantly intrudes the sequence within a few metres of the unexposed contact.

This unit apparently represents a series of interbeded felsic and mafic volcanic rocks or possibly a number of alternating, highly deformed, felsic and mafic dykes or perhaps a combination of

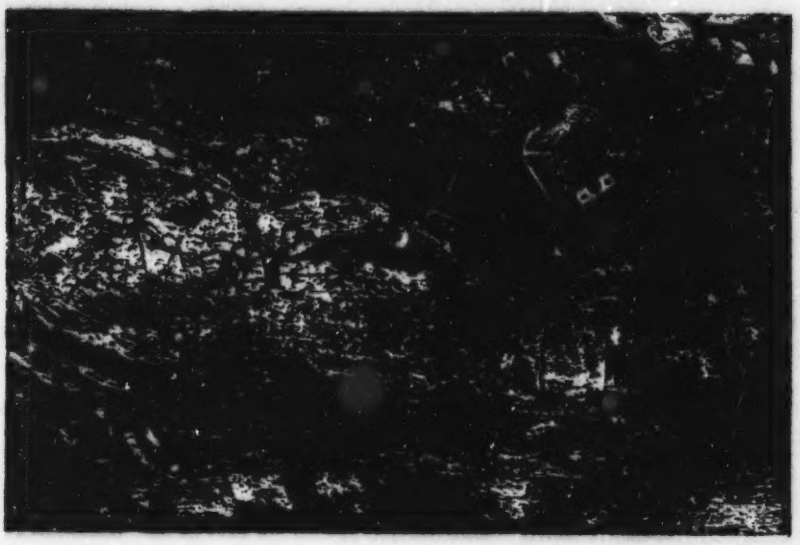

Figure 2. Massive quartzite bed interlayed with phyllite. The compass in this and subsequent photographs is oriented north.

Figure 3. Andalusite porphyroblasts on cleavage surface.

both.

Foliated granite (Unit Of): This unit comprises medium-grained, light grey to pink foliated granite that is best exposed at the Renous Airstrip. Cordierite-bearing sedimentary rocks along the side of the runway on the northeastern contact of this granite, contain a 3 m wide, fine-grained, foliated granite sill suggesting that the main body of granite intrudes the sedimentary rocks concordantly.

A granite exposure located 1.5 km east of the airstrip exhibits a prominent foliation that is crenulated by folding with a northeasterly trend. A massive, 15 cm wide, light pink, muscovite-bearing dyke striking 100° postdates the folds and is presumably an offshoot of the Devonian granite exposed 2 km to the north (Figure 4). The foliated granite appears to be continuous to the northeast with a northeasterly trending sill located 700 m south of the bridge over the Little Southwest Miramichi River.

NORTH POLE GRANITE

The Devonian intrusive rocks in the area are part of an 800 km^2 pluton named the North Pole Granite (Crouse 1979; Fyffe *et al.* 1981) in reference to the good exposures found near the mouth of North Pole Stream (Figure 5). The discordant nature of the pluton is particularly clear along its southern margin where the easterly trending granite contact truncates the southeasterly trend of the Ordovician and older country rocks. The country rocks contain cordierite and andalusite up to 2 km from the exposed pluton. Sillimanite occurs within 200 m of the contact south of Tuadook Lake.

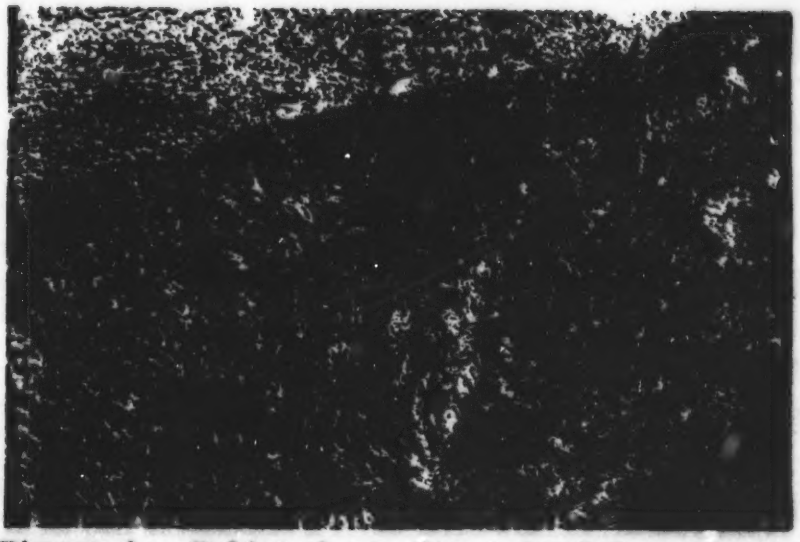

Figure 4. Foliated granite intruded by massive dyke (upper left).

The North Pole Granite has been divided into the following phases from oldest to youngest: diorite (Unit Dm), quartz-feldspar porphyry (Unit Df_1), biotite granite (Unit Df_2), leucocratic granite (Unit Df_3), microgranite and aplite, and diabase.

Diorite (Unit Dm): The diorite is fine medium-grained, dark grey and contains plagioclase, hornblende, biotite, quartz and alkali feldspar in order of abundance (Figure 6). It underlies relatively large areas on Sinclair Mountain, near the mouth of Indian Brook and west of Indian Lake. Elsewhere, the diorite is present as small clusters of subrounded inclusions ranging in diameter from 10 cm to 1 m irregularly veined by granite. The margins of the diorite inclusions are serrated and no chilling is observed in the granite veins indicating the diorite was warm and plastic when the granite was introduced (Figures 7, 8).

Quartz-feldspar porphyry (Unit Df_1): A fine-grained, grey quartz-feldspar porphyry is exposed on the main road southwest of Hickey Lakes and on logging roads to the north of this road. The porphyry contains quartz phenocrysts, 5 mm in diameter. and plagioclase phenocrysts, 1 cm in length, set in a quartzofeldspathic groundmass containing minor biotite.

The eastern contact of the porphyry with the main phase of the pluton (Unit Df_2) is angular, northerly trending, and steep. Biotite is enriched in the main phase at the contact (Figure 9). Within 2 m of the contact the porphyry contains an irregular pod of red granophyre and pegmatite roughly 1 m in diameter.

A vertical vein of the main granite trending 120° decreases in width from 50 to 5 cm over a 70 m distance from west to east across the porphyry before becoming covered by overburden. No

Figure 5. Granite exposure on North Pole Stream.

Figure 6. Equigranular texture of diorite.

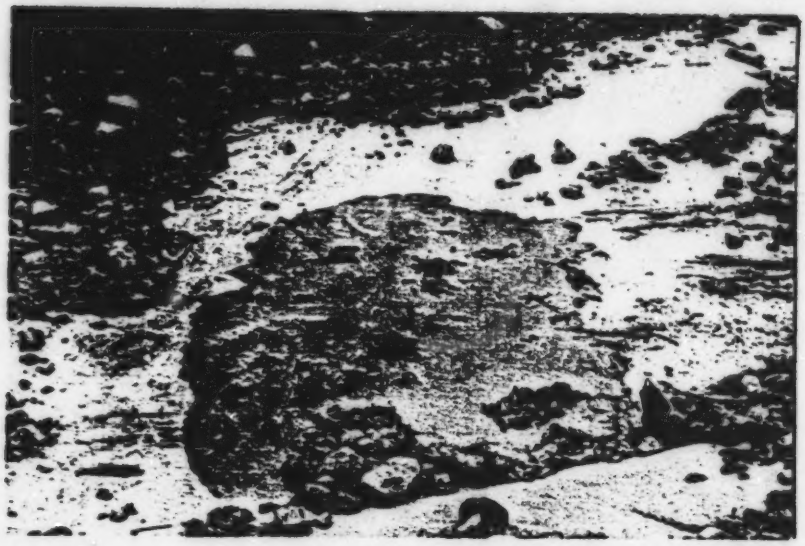

Figure 7. Diorite inclusion in granite.

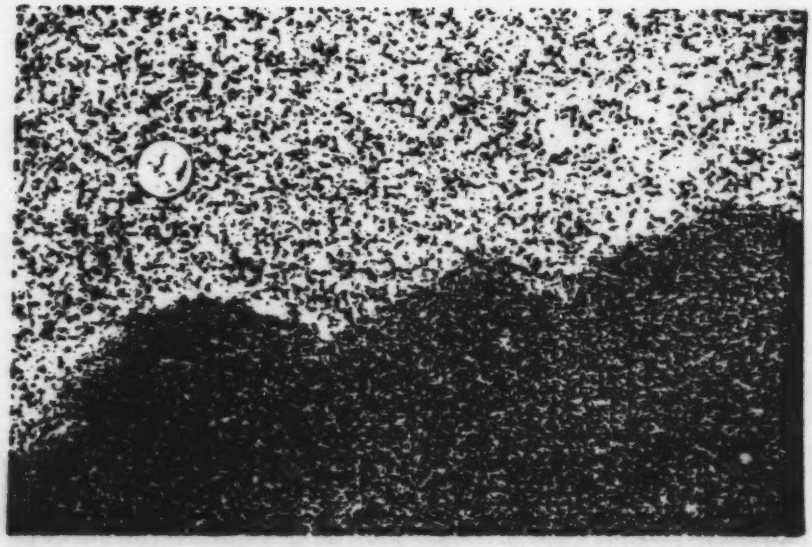

Figure 8. Close-up of serrated margin of diorite inclusion.

chilling is observed at the contacts of the vein (Figure 10). The porphyry is interpreted to represent the chilled margin of the main granite which subsequently intruded its own margin.

Biotite granite (Unit Df_2): Biotite granite forms the bulk of the North Pole pluton. The best exposures of this phase are found along Little Southwest Miramichi River downstream from the bridge and on North Pole Stream just above its mouth. Good exposures are also seen on the main road south of Hickey Lakes and along the logging road to Indian Lake.

The unit is a coarse medium-grained, light grey to light pink, equigranular to subporphyritic, biotite granite. Phenocrysts of alkali feldspar and plagioclase, locally exhibiting flow alignment, are generally 2 to 3 cm in length (Figure 11). Rapakivi texture and vugs of pegmatite are rare (Figure 12). Schlieren dipping moderately to the southeast occurs at the granite's contact with diorite south of Sinclair Mountain (Figure 13).

Leucocratic granite (Unit Df_3): Exposures on logging roads to the north of Lyles Mountain consist largely of equigranular, coarse-grained, locally pegmatitic, leucocratic granite containing considerably less biotite than the granite of Unit Df_2 (Figure 14). The granite is light pink where unaltered but is stained red where fractured and flooded with quartz.

The northern contact of the leucocratic granite with grey subporphyritic granite of Unit Df_2 is exposed on the more northerly logging road. The contact trends east-west (Figure 15) with irregular veins of the pink leucogranite invading the grey granite which locally contains a number of diorite xenoliths.

The coarse-grained leucocratic granite is intruded by numerous

Figure 9. Contact between quartz-feldspar porphyry to the west with biotite-rich granite to the east.

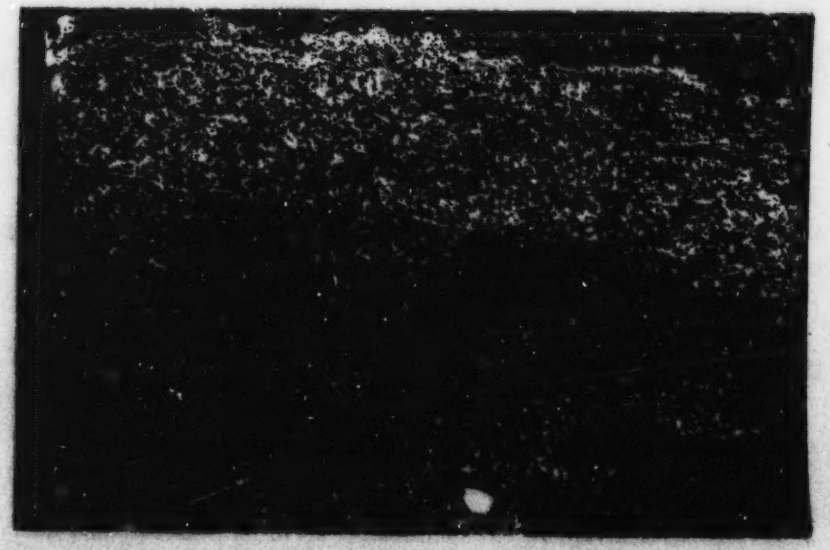

Figure 10. Quartz-feldspar porphyry intruded by granite vein.

Figure 11. Flow alignment of feldspar in subporphyritic granite.

Figure 12. Pegmatite vug in subporphyritic granite.

Figure 13. Schlieren in granite south of Sinclair Mountain.

Figure 14. Equigranular leucocratic granite.

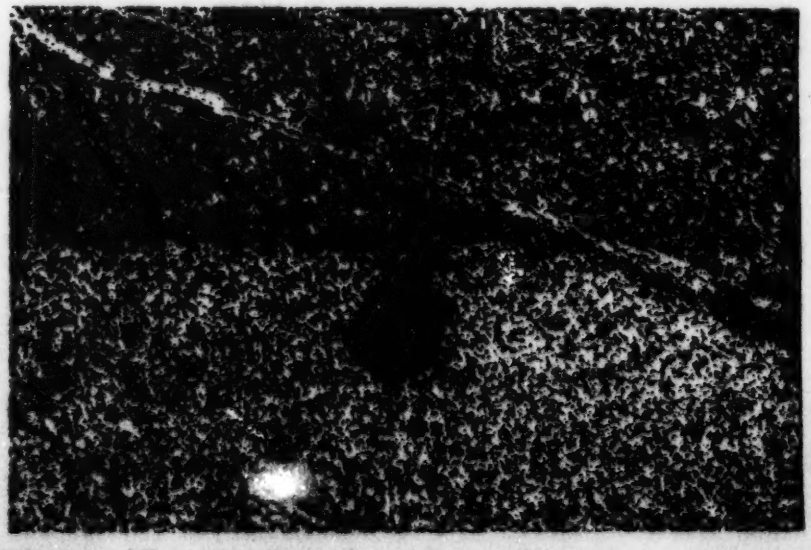

Figure 15. Contact between subporphyritic granite to the north with leucocratic granite to the south.

southeasterly trending dykes of white, equigranular microgranite ranging from 15 cm to 10 m in width (Figure 16). The largest of these comprises two phases - one containing more biotite than the other - with an irregular contact between the two (Figure 17). The dykes contain minor muscovite.

Red microgranite: This unit occurs as two southeasterly trending dykes - one southwest of Hickey Lakes is about 100 m wide and the other west of Indian Lake is at least 15 m wide, although along strike to the northwest it quickly reduces to a width of 1 m (Figure 18). The dykes are fine- to fine medium-grained and contain biotite partly altered to chlorite. They are probably equivalent to the more abundant fine-grained aplites but have obtained a coarser grain size because of their greater width.

Pink aplite: Aplite dykes varying in width from 1 to 60 cm intrude diorite and the main granite phases of the North Pole pluton. They generally strike to the east-southeast but a few trend to the northeast (Figures 19, 20, 21). The dykes follow joint trends but have wavy contacts indicating emplacement while the host rock was still warm and ductile (Figures 19, 20).

Diabase: Diabase dykes are found on the main road southwest of Sinclair Mountain and Hickey Lakes and on the Little Southwest Miramichi River just downstream from the mouth of Little North Pole Stream. The dykes are dark grey, fine-grained, and trend to the southeast. Southwest of Sinclair Mountain, two parallel dykes, one 35 cm and the other 15 cm in width, follow joints in diorite (Figure 22). One of these dykes can be seen to be truncated by a northeasterly trending joint (Figure 23). The diabase on the Little Southwest Miramichi River is 1 m in width and intrudes

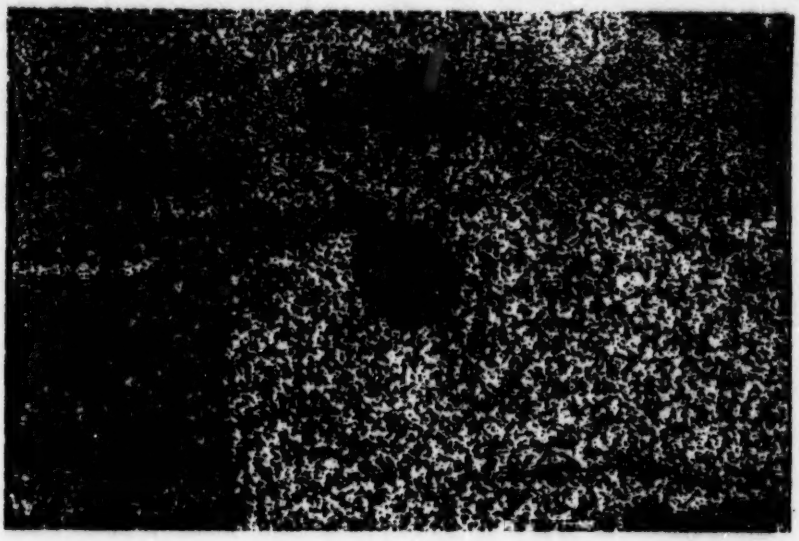

Figure 16. White microgranite dyke intruding leucocratic granite.

Figure 17. Contact between darker biotite-rich and lighter biotite-poor microgranite.

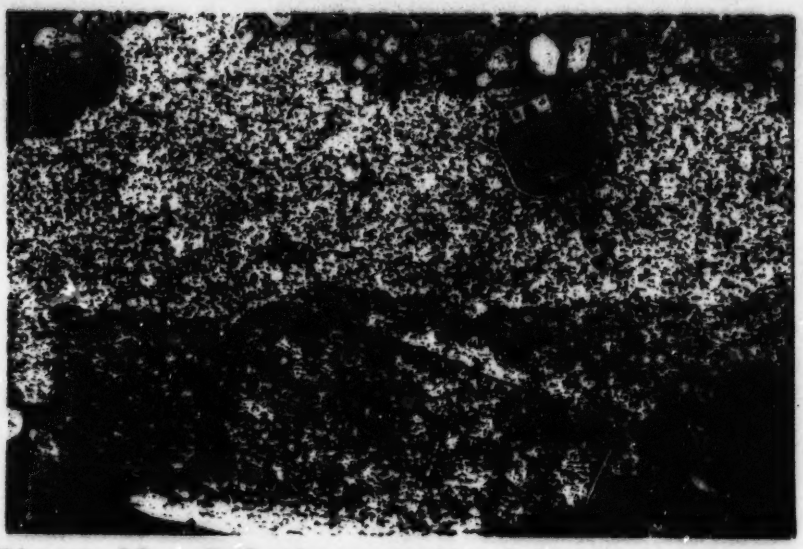

Figure 18. Red microgranite intruding granite west of Indian Lake.

Figure 19. East-southeasterly trending aplite dyke intruding diorite.

Figure 20. Easterly trending aplite dyke in granite.

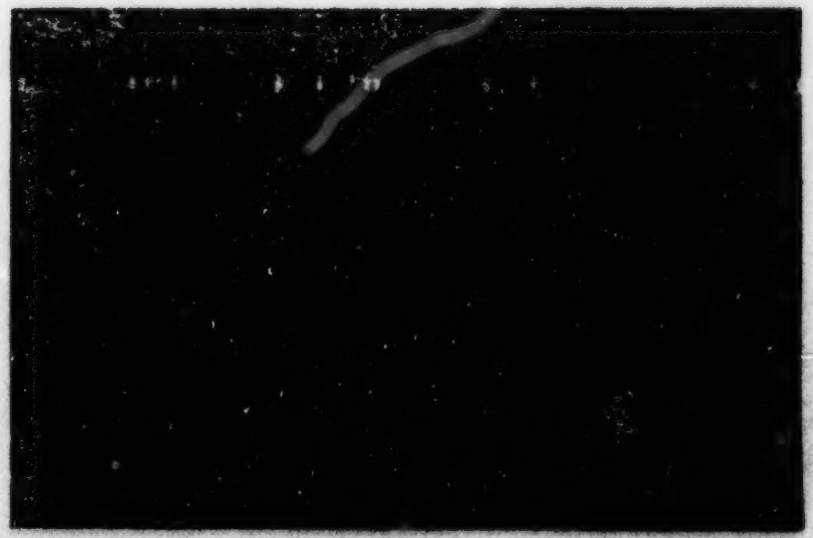

Figure 21. Northeasterly trending aplite dyke in granite.

Figure 22. Diabase dyke intruding diorite.

Figure 23. Diabase dyke truncated by north-easterly trending joint (left-centre of photograph).

sheared medium-grained biotite granite (Figures 24, 25). A sheared 1.5 m wide diabase southwest of Hickey Lakes intrudes the centre of a red microgranite dyke showing that the diabase dykes are the youngest intrusions in the area.

Depth of emplacement: An estimate of the depth of emplacement for the North Pole pluton can be determined from the stability fields of the minerals present in the pluton and country rocks. The occurrence of andalusite in the contact aureole restricts the pressure to less than 3.76 kbars (Holdaway 1971) representing a depth of approximately 13 km. The presence of primary muscovite in minor phases of the granite suggests crystallization at a pressure in excess of 3.5 kbars, *i.e.* at a depth greater than 12 km (Carmichael *et al.* 1974). Partial melting of sedimentary rocks along the southern contact indicates a temperature in the order of 700°C (Winkler 1967).

The presence of a pegmatitic phase on Lyles Mountain (Unit Df_3) along with roof pendants of the chilled margin (Unit Df_1) and sedimentary rocks suggest that only the uppermost level of the pluton has been removed by erosion.

Age: The North Pole Granite has always been considered as Devonian because its massive appearance is similar to other plutons known to intrude Devonian strata (Shaw 1936; Anderson 1970*a*, *b*; Skinner 1975). Shaw and Anderson considered the foliated Ordovician granite to be an early phase of Devonian plutonic activity but this has been disproven (Poole 1963; Fyffe *et al.* 1977; Poole 1980).

In 1979 samples were collected from the North Pole Granite and sent to R.F. Cormier of St. Francis Xavier University in Nova

Figure 24. Diabase dyke intruding granite on Little Southwest Miramichi River (arrows show contact).

Figure 25. Contact of the same massive dyke with fractured granite (arrows point to diabase).

Scotia for an age determination. The results of this Rb-Sr whole rock study are given below in Table 1 and Figure 26. Samples taken from diorite (Unit Dm, samples 3, 10), quartz-feldspar porphyry (Unit Df_1, sample 5), the main phase of biotite granite (Unit Df_2, samples 2, 4, 6, 7, 8, 9), and from a red microgranite dyke (sample 1) are assumed to be comagmatic and to have been intruded over a relatively short period of time in accord with the geological evidence presented above. The data yields an age of 378±7 Ma which is Middle Devonian.

Chemical analyses: X-ray fluorescence analyses of the North Pole pluton were performed at the Sussex office of the Mineral Resources Division in 1974 from specimens collected in 1972. The analyses (Table 2) are from samples of the main biotite granite phase (Unit Df_2) and from diorite (Unit Dm). As pointed out by Fyffe *et al.* (1981), the granite is chemically and texturally similar to the Pokiok batholith of southwestern New Brunswick and to the South Mountain batholith of Nova Scotia although the Nova Scotia granite appears to be more peraluminous.

JOINTS AND FAULTS

The North Pole pluton is generally massive and transected by numerous joints. The same joints exist in the country rocks but are less conspicuous because of the earlier deformation in these rocks. The prominent joint system is a steeply dipping to vertical orthogonal set with an average trend of 30° and 120° (Figure 27). The joints are generally spaced from 5 cm to 2 m apart with the most common spacing being about 1 m (Figure 28). The 120°

Sample No.	Latitude N	Longitude W	Rb (ppm)	Sr (ppm)	87Rb/86Sr	87Sr/86Sr
1	46°59'55"	66°31'52"	287	10.2	85.2	1.1629
2	47°00'28"	66°32'38"	266	28.5	27.4	0.8514
3	47°01'00"	66°34'41"	213	30.0	20.9	0.8249
4	47°03'15"	66°37'32"	335	81.8	12.0	0.7621
5	46°59'50"	66°31'30"	255	107	6.96	0.7425
6	46°59'50"	66°31'30"	157	219	2.08	0.7152
7	47°03'05"	66°37'15"	154	237	1.89	0.7092
8	47°01'55"	66°36'23"	107	274	1.13	0.7084
9	46°58'35"	66°31'23"	109	309	1.03	0.7090
10	47°01'00"	66°34'41"	81.8	280	0.846	0.7079

TABLE 1. Radiometric data - North Pole Granite

TABLE 2

Chemical Analysis and Norms (weight percent)

	CIANITE											DIORITE				
Latitude S	47°11'18"	47°07'48"	47°07'24"	47°07'18"	47°06'42"	47°04'24"	47°04'24"	46°58'48"	46°59'00"	46°58'36"	46°58'48"	46°58'42"	46°58'42"	46°58'42"	46°58'30"	47°08'12"	46°58'42"	46°58'42"	46°58'42"	46°58'30"	47°08'12"
Longitude W	66°25'30"	66°30'00"	66°29'42"	66°28'48"	66°32'12"	66°..'36"	66°33'36"	66°28'30"	66°28'42"	66°28'00"	66°35'00"	66°31'24"	66°31'24"	66°31'24"	66°31'42"	66°34'36"	66°31'24"	66°31'24"	66°30'42"	66°31'42"	66°34'36"
SiO_2	74.84	71.47	69.42	68.36	71.65	66.91	73.50	67.88	67.08	68.82	68.35	66.25	59.92	59.07	58.62	62.62	61.60	61.60	61.60	61.60	61.60
Al_2O_3	13.09	14.25	14.81	15.67	13.28	14.45	12.94	15.97	15.15	14.61	14.70	14.53	15.59	15.97	16.31	16.13	15.60	15.60	15.60	15.60	15.60
Fe_2O_3	1.75	2.60	3.12	3.27	3.33	4.18	2.60	5.16	3.99	3.87	4.06	4.95	7.37	7.57	7.35	5.90	7.70	7.70	7.70	7.70	7.70
CaO	1.05	1.38	2.54	1.96	2.41	2.41	1.57	2.64	3.26	2.66	2.70	4.22	6.85	6.85	6.82	5.96	4.60	4.60	4.60	4.60	4.60
MgO	0.50	0.84	1.16	1.17	1.37	1.48	0.94	2.09	1.60	1.54	1.70	2.60	4.03	4.09	4.46	3.02	2.59	2.59	2.59	2.59	2.59
Na_2O	3.71	3.28	3.62	3.31	3.16	3.27	3.47	2.74	3.61	3.34	3.52	2.69	3.31	3.45	3.16	3.11	3.16	3.16	3.16	3.16	3.16
K_2O	4.92	5.53	4.35	5.33	4.04	4.38	4.12	3.56	3.59	4.21	3.95	3.75	1.56	1.50	1.98	1.89	2.93	2.93	2.93	2.93	2.93
TiO_2	0.21	0.43	0.56	0.62	0.55	0.70	0.35	0.65	0.70	0.69	0.74	0.78	1.06	1.15	0.89	0.99	1.35	1.35	1.35	1.35	1.35
P_2O_5	0.05	0.16	0.16	0.26	0.14	0.14	0.09	0.15	0.21	0.19	0.19	0.13	0.16	0.20	0.24	0.27	0.35	0.35	0.35	0.35	0.35
MnO	0.07	0.07	0.06	0.05	0.07	' 08	0.07	0.10	0.07	0.08	0.08	0.10	0.15	0.15	0.17	0.11	0.12	0.12	0.12	0.12	0.12
Q	31.6	27.5	24.4	23.5	31.2	26.0	33.2	29.6	23.8	25.6	25.0	23.9	14.7	13.1	11.6	20.6	17.9	17.9	17.9	17.9	17.9
OR	29.1	32.7	26.9	31.6	23.9	...0	24.5	21.4	21.4	24.9	23.4	22.2	9.2	8.9	11.8	11.2	17.4	17.4	17.4	17.4	17.4
AB	31.4	27.8	30.7	28.0	26.8	27.7	29.5	23.4	30.8	28.3	29.8	22.8	28.1	29.3	26.7	26.4	26.7	26.7	26.7	26.7	26.7
AN	4.0	5.8	10.7	8.0	10.1	11.1	7.2	12.3	14.7	12.0	12.2	16.5	23.2	23.8	24.7	24.6	19.4	19.4	19.4	19.4	19.4
C	-	0.7	-	1.5	-	0.3	0.1	1.2	-	0.2	0.2	-	-	-	-	-	-	-	-	-	-
DI	0.7	-	0.7	-	0.7	-	-	-	0.2	-	-	2.4	5.8	5.3	4.5	2.1	1.2	1.2	1.2	1.2	1.2
HE	-	-	-	-	-	-	-	-	-	-	-	0.5	2.2	2.0	1.8	0.5	0.6	0.6	0.6	0.6	0.6
EN	0.9	2.1	2.6	2.9	3.1	3.7	2.4	5.3	3.9	3.8	4.2	5.4	7.4	7.8	9.1	6.6	5.9	5.9	5.9	5.9	5.9
FS	-	-	-	-	-	".6	-	1.5	0.1	-	0.1	1.2	3.2	3.3	4.1	1.9	3.3	3.3	3.3	3.3	3.3
MT	-	0.9	1.6	1.7	2.3	3.2	0.8	3.4	3.2	3.1	3.3	3.3	3.7	3.9	3.5	3.6	4.2	4.2	4.2	4.2	4.2
IL	0.2	0.8	1.1	1.2	1.0	1.3	0.7	1.6	1.3	1.3	1.4	1.5	2.0	2.2	1.7	1.9	2.6	2.6	2.6	2.6	2.6
HM	1.7	1.2	0.9	0.9	0.4	-	1.3	-	-	-	-	-	-	-	-	.-	-	-	-	-	-
AP	0.1	0.4	0.4	0.6	0.3	0.3	0.2	0.4	0.5	0.4	0.4	0.3	0.4	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8

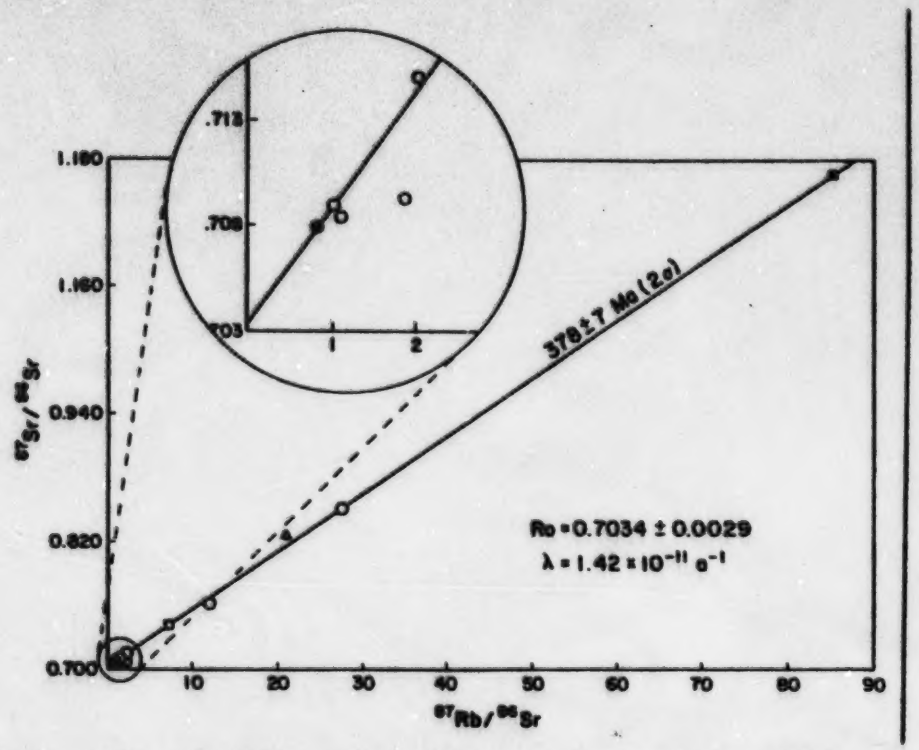

Figure 26. Rubidium-strontium whole rock isochron. ● diorite (Unit Dm); △ white granite vein in diorite; □ quartz-feldspar porphyry (Unit Df_1); ○ biotite granite (Unit Df_2); ■ red microgranite dyke.

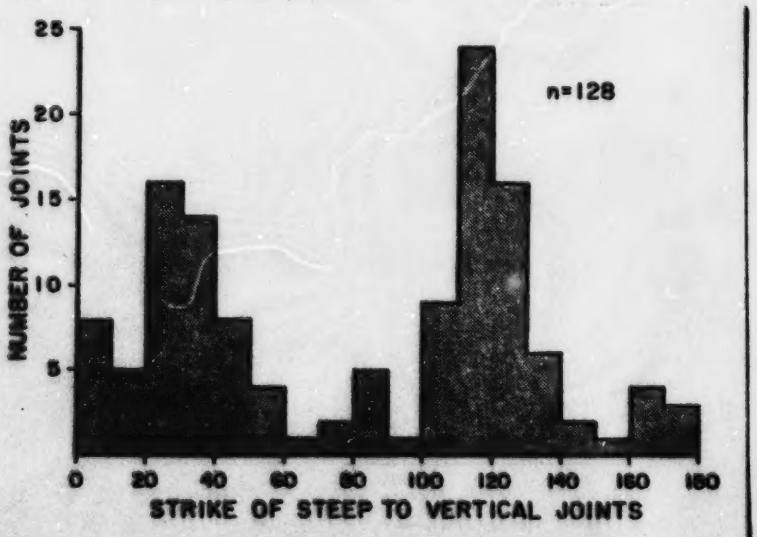

Figure 27. Histogram of joint strike frequency.

joints are usually the better developed of the set; this is reflected in the east-southeasterly flow of the Little Southwest Miramichi River and Indian Brook. Aplites, diabase and narrow quartz veins also strike in this direction (Figures 29, 30). East-southeasterly trending joints are also dominant in the Burnthill area located 40 km to the southwest (Potter 1969).

Local intense shearing also occurs in an east-southeasterly direction. On the main road south of Sinclair Mountain, a steep mylonitic fabric within a red microgranite dyke strikes between 95° and 115° (Figure 31) and is kinked by small folds trending 150°. The deformation at this location clearly predates development of the joints (Figure 32).

Along strike to the southeast on the main road southwest of Hickey Lakes, the margin of a microgranite dyke and the coarser granite that it intrudes possess a cataclastic fabric of evenly spaced fractures (Figure 33) and locally form a tectonic breccia (Figure 34). A diabase dyke which intrudes the microgranite is also sheared.

The coarse-grained granite on the margin of a diabase dyke on the Little Southwest Miramichi River is deformed up to 1 m from the contact but the dyke itself appears undeformed (Figure 25).

Orthogonal joint systems may form as a result of loading and unloading producing load-parallel and release joints at right-angles to each other (Lajtai and Stringer 1981). This is consistent with the intrusion of dykes in east-southeast tension zones parallel to the loading direction that existed in this area during the Devonian period (Fyffe *et al.* 1981). Aplite dykes generally have irregular margins and were injected previous to the full develop-

Figure 28. Orthogonal joints in red micro-granite west of Indian Lake.

Figure 29. Aplite dyke more-or-less following east-southeasterly trending joints in sub-porphyritic granite.

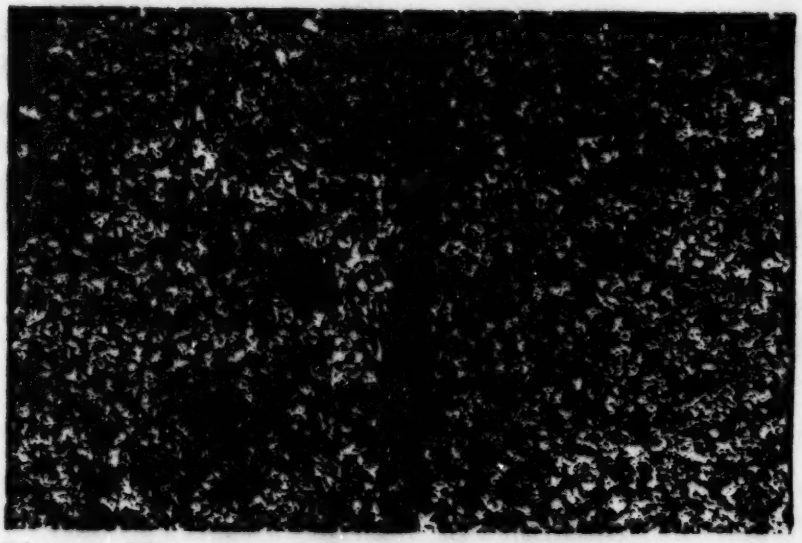

Figure 30. East-southeasterly trending quartz vein in leucocratic granite north of Lyles Mountain.

Figure 31. Mylonitic fabric in microgranite dyke south of Sinclair Mountain.

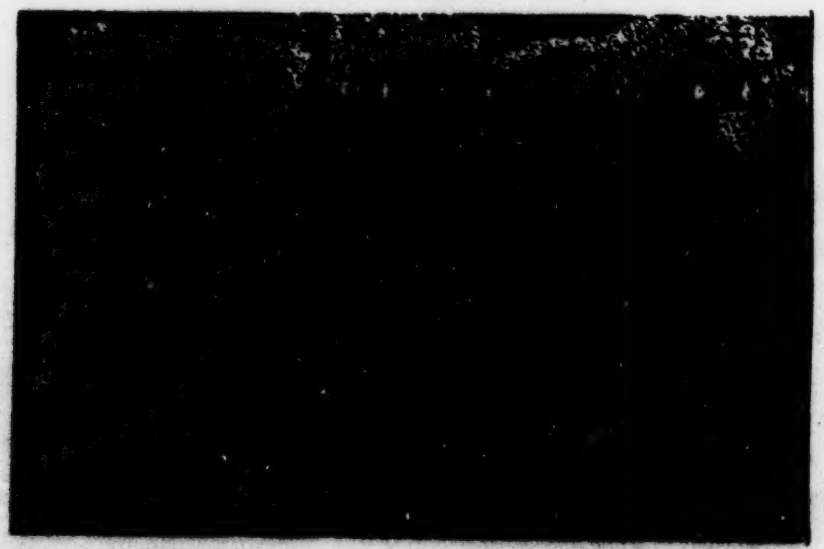

Figure 32. East-southeasterly trending joint postdating mylonitic fabric in microgranite dyke.

Figure 33. Fractured granite on main road southwest of Hickey Lakes.

Figure 34. Brecciated granite on main road southwest of Hickey Lakes.

ment of the joints. No dykes occur along the north-northeast release joints that developed during relaxation of the stress after the pluton was fully consolidated. A diabase dyke southwest of Sinclair Mountain is offset by a north-northeasterly trending joint (Figure 23).

Subhorizontal joints were observed on exposed vertical joint faces in a small outcrop 0.5 km north of Indian Brook and in the many large outcrops along the Little Southwest Miramichi River (Figure 35).

A less prominent orthogonal set of generally steeply dipping joints and fractures trend 0° and 90° (Figure 27). This joint system may have been produced by a more recent stress field (Lajtai and Stringer 1981; Engelder and Sbar 1976). A joint striking 5° within a large diorite inclusion southwest of Indian Lake dips 40° westward (Figure 36) and appears to have been recently offset (John Adams, *personal communication*, 1982). The western joint face has been displaced upward by 2 cm and shows no rounded edges that would be expected from long exposure to erosion (Figure 37). The movement on the joint plane is in agreement with the fault plane solution obtained for the Miramichi Earthquake (Hasegawa 1982).

Figure 35. Subhorizontal joints in granite on Little Southwest Miramichi River.

Figure 36. Northerly trending joint dipping to the west. Easterly trending joint can be seen just south of compass.

Figure 37. Two centimeter upward offset on western joint face.

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